Experimental support for evaluation of the Victoria Class Virtual Submarine (VCVS)

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In conducting the research described in this report, the investigators adhered to the policies and procedures set out in the Tri-Council Policy Statement: Ethical conduct for research involving humans, National Council on Ethics in Human Research, Ottawa, 1998 as issued jointly by the Canadian Institutes of Health Research, the Natural Sciences and Engineering Research Council of Canada and the Social Sciences and Humanities Research Council of Canada.

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Abstract

CAE Professional Services (Canada) Inc. (CAE PS) was contracted by Defence Research and Development Canada (DRDC) Toronto to conduct work in accordance with a Call-up under Contract Number W7711-068111. The intent of the Call-up was to provide experimental support to DRDC Toronto in the evaluation of the Victoria Class Virtual Submarine (VCVS); DRDC Toronto designed the experiment and CAE PS assisted in the execution of the project. The evaluation of the VCVS was conducted in accordance with Protocol Number L-809 (Magee, Cain, & Thompson, 2011), an experimental protocol approved by the DRDC Human Research Ethics Committee (HREC).The VCVS is a game-based software program designed to deliver training to military personnel in a simulated submarine environment. This document describes the implementation of the protocol, provides qualitative findings and identifies the limitations and lessons learned from the conduct of the work. The results of the behavioural studies are reported separately by DRDC Toronto.

Résumé

Recherche et développement pour la défense Canada (RDDC) Toronto a attribué un contrat à CAE Services professionnels (Canada) Inc. (CAE SP) en vue d’effectuer le travail conformément à la commande du numéro de contrat W7711-068111. L’objectif de cette commande était de fournir un soutien expérimental à RDDC Toronto dans le cadre de l’évaluation du sous-marin virtuel de la classe VICTORIA (SVCV); RDDC Toronto a conçu l’expérience et CAE SP a participé à la réalisation du projet. L’évaluation du SVCV a été menée conformément au numéro de protocole L-809 (Magee, Cain et Thompson, 2011) : un protocole expérimental approuvé par le Comité d’éthique en matière d’étude sur des sujets humains (CEESH) de RDDC. Le SVCV est un logiciel basé sur le jeu conçu afin de donner de la formation aux militaires dans un environnement de sous-marin virtuel. Le présent document décrit la mise en œuvre du protocole, présente les résultats qualitatifs et détermine les limites et les leçons retenues de la réalisation du travail. Les résultats des études sur le comportement font l’objet d’un rapport distinct de RDDC Toronto.

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Executive summary

Experimental support for evaluation of the Victoria Class Virtual Submarine (VCVS)

Lochlan E. Magee; DRDC Toronto CR 2012-013; Defence R&D Canada – Toronto; March 2012.

Introduction or background: The Canadian Navy eLearning Centre of Expertise (NeLCoE) developed the Canadian Virtual Naval Fleet (CVNF), a game-based, desk-top, virtual environment for training maritime procedures and for familiarizing trainees with the spatial structures of large naval vessels that are often unavailable for on-board training. The Director Maritime Training and Education (DMTE) requested an objective investigation of the training effectiveness of Victoria Class Virtual Submarine (VCVS), one of the first implementations of the CVNF. Defence R&D Canada (DRDC) – Toronto engaged CAE Professional Services (Canada) Inc. to implement an experimental protocol that was conceived by DRDC Toronto. The main purposes of the experimental protocol were to gain behavioural information about the training effectiveness of the VCVS and to determine the need for further development of the hardware or software. A complex task was used for the assessment. It involved the isolation of a bulkhead, which is performed if a fire or flood occurs within the submarine. Qualified submariners must know the locations, names, functions, and operations of the valves and tools that are needed to perform this drill. Participants learned and performed the task to criterion within the VCVS, aboard HMCS Corner Brook, or both.

Results: This report (1) describes how the experimental protocol was implemented, (2) provides summary data that describe the participants, (3) includes observations made by the experimenters during the conduct of the study, (4) provides anecdotal reports made by the participants, (5) identifies deficiencies in the simulation and their impact on performance, (6) provides a method and specific recommendations for correcting deficiencies with the simulation, (7) provides observations that could affect the interpretation of the results of the behavioural analyses, which are reported separately, and (8) offers first-hand observations and opinions about the usefulness of the VCVS.

Significance: The report provides assurance that the experimental protocol was implemented as planned. It also provides observations helpful to the interpretation of the behavioural results (reported separately), guidance for improving the VCVS for future use by the Royal Canadian Navy, and lessons-learned for future behavioural studies of this type.

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Sommaire

Experimental support for evaluation of the Victoria Class Virtual Submarine (VCVS)

Lochlan E. Magee ; DRDC Toronto CR 2012-013 ; R & D pour la défense Canada – Toronto; mars 2012.

Introduction ou contexte : L'équipe du Centre d'expertise de l'apprentissage en ligne de la Marine canadienne a développé une flotte navale virtuelle canadienne (FNVC), c'est-à-dire un environnement virtuel pour ordinateur basé sur le jeu, à des fins de procédures de formation maritime et pour familiariser les stagiaires avec les structures spatiales de larges navires qui ne sont pas toujours disponibles pour pouvoir y donner de la formation à bord. Le Directeur – Instruction et éducation maritimes (DIEM) a demandé la tenue d'une enquête objective de l'efficacité de la formation avec le sous-marin virtuel de la classe VICTORIA (SVCV), l'une des premières initiatives de la FNVC. R & D pour la défense Canada (RDDC) Toronto a demandé à CAE Services professionnels (Canada) Inc. de mettre en place un protocole expérimental conçu par RDDC Toronto. Les objectifs principaux du protocole expérimental étaient d'acquérir de l'information sur le comportement concernant l'efficacité de la formation avec le SVCV, ainsi que de déterminer s'il est nécessaire de pousser le développement du matériel ou du logiciel. Une tâche complexe a été réalisée pour l'évaluation. Pour ce faire, il a fallu isoler une cloison; il est possible de le faire si un incendie ou une inondation se produit dans le sous-marin. Les sous-mariniers qualifiés doivent connaître les emplacements, les noms, les fonctions et les opérations des valves et des outils qui sont nécessaires aux fins de l'exercice. Les participants ont tiré des leçons et ont effectué la tâche en fonction des critères du SVCV, à bord du NCSM CORNER BROOK, ou les deux.

Résultats : Le présent rapport (1) décrit comment le protocole expérimental a été mis en œuvre, (2) fournit des données sommaires décrivant les participants, (3) comprend les observations des expérimentateurs pendant la tenue de l'étude, (4) présente les rapports isolés des participants, (5) relève les lacunes liées à la simulation et leurs répercussions sur le rendement, (6) fournit une méthode et des recommandations précises pour corriger les lacunes liées à la simulation, (7) indique des observations qui pourrait avoir des répercussions sur l'interprétation des résultats des analyses comportementales (sujet d'un rapport distinct), et (8) présente des observations et des opinions de première main sur l'utilité du SVCV.

Importance : Ce rapport fournit l'assurance que le protocole expérimental a été mis en œuvre comme prévu. De plus, il présente des observations utiles en vue de l'interprétation des résultats comportementaux (sujet d'un rapport distinct), oriente l'amélioration du SVCV à des fins

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d'utilisation future par la Marine royale canadienne, puis indique les leçons retenues en vue d'autres études comportementales de ce genre.

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REVISION HISTORY

Revision	Reason for Change	Origin Date
Version 01	Initial document (draft version) issued to Dr. L. Magee (DRDC Toronto)	24 January 2012
Version 02	Revised draft version (version 01) according to feedback received from Dr. L. Magee and Dr. A. Thompson	15 March 2012
Version 03	Final Version - Revised draft version (version 02) according to feedback received from Dr. L. Magee and Dr. A. Thompson	27 March 2012

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1. Introduction

The Royal Canadian Navy (RCN) faces increasing challenges and setbacks to deliver Victoria Class Submarine training to naval personnel. These training challenges are augmented by limitations to gaining physical access to the Victoria Class Submarines. To address these challenges the Canadian Navy eLearning Centre of Expertise (NeLCoE) developed the Victoria Class Virtual Submarine (VCVS); the VCVS is a game-based software program designed to deliver training to naval personnel in a simulated environment. The objective of the VCVS is to train personnel on the spatial layout of the submarine and the conduct of onboard procedural tasks.

The Director Maritime Training and Education (DMTE) requested support from Defence Research and Development Canada (DRDC) Toronto to design and conduct a scientific study to evaluate the VCVS *as a future training platform for RCN personnel.* DRDC Toronto contracted CAE Professional Services (Canada) Inc. (CAE PS) to provide additional experimental support during the execution of the study. Over a four week period, CAE PS provided assistance with conducting the experiment aboard Her Majesty's Canadian Ship (HMCS) Corner Brook, while alongside at Her Majesty's Canadian (HMC) Dockyard Esquimalt, and in a classroom at the Canadian Forces Base (CFB) Esquimalt, British Columbia. The experiment was conducted in accordance with Protocol Number L-809 (Magee, Cain, & Thompson, 2011) which received formal approval from the DRDC Human Research Ethics Committee (HREC).

Scope

This technical report is the deliverable prepared in accordance with the requirements for Call-up. This document describes the implementation of the protocol, quantitative and qualitative findings and identifies the limitations and lessons learned from the conduct of the work. The behavioural results are reported more fully by DRDC Toronto in a technical report.

2. pre-Experiment Tasks

In providing experimental support to DRDC Toronto during the evaluation of the VCVS, CAE PS executed a series of general tasks throughout the conduct of this project (see Annex A). In addition, a series of pre-experimental tasks was completed prior to executing the testing sessions aboard HMCS Corner Brook.

Pre-experimental tasks executed aboard HMCS Corner Brook included:

a) Signing in with HMCS Corner Brook Commissionaire, prior to boarding HMCS Corner Brook;

b) Notifying HMCS Corner Brook Duty Watch Supervisor (DWS) of physical presence aboard HMCS Corner Brook;

c) Signing the experimenter and all participants in and out on HMCS Corner Brook accountability sheet; and,

d) Requesting a qualified submariner perform safety briefings on the use of the Emergency Breathing System (EBS) and the Emergency Escape Breathing Device (EEBD) prior to his participation in the study aboard HCMS Corner Brook.

3. methodology

The following sub-sections describe the implementation of the protocol.

Study Participants

The following section describes the characteristics of each of the participant groups included in the VCVS study. The RCN personnel who participated in the study were divided into three testing groups based upon their prior experience task-qualified credentials.

Qualified, Experimental and Control Participants

Participants with very little or no experience working aboard submarines were assigned to either the Control or Experimental groups; none of these participants had experience with isolating bulkhead 35. The Control group (N=10 males; mean age = 28.5 years) and the Experimental group (N=10 males; mean age 23.4 years) consisted of either Personnel Awaiting Training (PATs) or RCN non-commissioned members. The third testing group, identified as the Qualified group, consisted of experienced and task-qualified submariners (N=10 males; mean age = 39.6 years). Table 3-1 presents the age-related descriptive data for each of the participant groups. The Personnel Coordination Centre of Maritime Forces Pacific recruited available participants from various local units.

Table 3-1: Descriptive Statistics upon Participant Age Categorized by Group

Group	Age (Years)			
	Mean	SD	Maximum	Minimum
Qualified	39.6	8.5	50	26
Experimental	23.4	6.5	35	18
Control	28.5	9.6	49	20

In addition to providing their age, participants provided service experience and video game experience. With respect to service experience, all participants were asked to provide the total number of years they have served on both submarines and/or ships. Table 3-2 and Table 3-3 present data pertaining to service experience (submarine and ship) for each participant group. These tables demonstrate that Experimental and Control participants in this study had little to no experience aboard submarines and ships. The experience was measured in years for the Qualified group, however, the experience was measured in hours for the Control and Experimental groups.

Table 3-2: Descriptive Statistics for Qualified Participant Service Experience

Group	Total Number of Service Experience Years							
	Submarine				Ship			
	Mean	SD	Max	Min	Mean	SD	Max	Min

Qualified	9.7	7.4	25	1.5	3.4	3.0	10	0

Table 3-3: Descriptive Statistics for Experimental and Control Participant Service Experience

Group	Service Experience							
	Submarine (Total Number of Hours)				Ship (Total Number of Weeks)			
	Mean	SD	Max	Min	Mean	SD	Max	Min
Experimental	0.03	0.10	0.33	0.00	12.02	32.36	104.00	0.00
Control	1.71	5.03	16.00	0.00	37.21	114.83	364.00	0.00

Group mean video game experience data are presented below in Table 3-4. These results demonstrate that overall the Qualified participants were the most experienced video game players. However, on average the Experimental participants tended to have more video game experience on a weekly basis compared to the other two groups.[1]

Table 3-4: Descriptive Statistics for Participant Video Game Experience Categorized by Group

Group	Video Game Experience							
	Total Number of Years				Number of Hours/ Week Playing			
	Mean	SD	Max	Min	Mean	SD	Max	Min
Qualified	12.9	10.9	30	0	3.5	7.0	20	0
Experimental	8.9	7.8	25	0	5.6	6.3	17.5	0
Control	10.1	8.1	22	0	3.2	4.3	10	0

Materials & Design

In order to evaluate the effectiveness of the VCVS in training personnel on the spatial layout and procedural tasks associated with Victoria Class submarines, two experiments were conducted which required participants to isolate bulkhead 35 in the simulated VCVS environment and/ or aboard HMCS Corner Brook.

The first experiment was designed to assess reverse transfer of training effects that might be associated with the VCVS by comparing the number of trials required by the Qualified and Experimental participants to successfully isolate bulkhead 35 one time without error in the VCVS (highlighted as blue in Table 3-5 below).

The second experiment, designed to assess forward transfer of training effects associated with the VCVS, compared the number of trials Experimental and Control participants required to isolate bulkhead 35 one time perfectly aboard HMCS Corner Brook (highlighted as green in Table 3-5 below). Table 3-5 below describes the experimental design for all three participant groups. The Qualified Group participated only

[1] Each participant provided an estimate to reflect his overall experience playing video games and his experience playing on a weekly basis. The mean level of experience for each element was calculated on the basis of these estimated ranges.

in the VCVS familiarization and skill acquisition session as they had previously achieved their qualifications to perform these tasks aboard the submarine.

Table 3-5: Experimental Design Associated with the Study

Group	Experimental Design		
	Session 1		Session 2
	VCVS Familiarization and Skill Acquisition Session	Submarine Familiarization Session	Submarine Skill Acquisition Session
Control		X	X
Experimental	X		X
Qualified	X		

During all skill acquisition trials, compartment (forward or aft) and environmental (VCVS or submarine) specific scoring sheets (See Annex B, C, D and E), designed by the experimenters, were used to record each participant's spatial and procedural task performance associated with isolating bulkhead 35. To successfully isolate bulkhead 35, participants had to correctly locate, identify, explain the function and operation of six valves associated with isolating bulkhead 35 one time without error from either the forward or aft compartment. Participants were instructed that the order in which they shut the six valves was unimportant, but that they must take the most direct route possible for a successful completion. Throughout the skill acquisition trials, participants were allowed to ask for assistance and were given immediate corrective feedback from the experimenters when an error was committed. In order to gain consensus upon the scoring of spatial and procedural tasks associated with isolating bulkhead 35, the experimenters (C. Kersten and Dr. A. Thompson) collectively evaluated the first four Experimental participants and all 10 Qualified participants.

Procedure

After briefing participants on their rights, roles and responsibilities associated with their participation in the VCVS experiment, participants were asked to complete the consent form and were given the opportunity to read the Protocol Number L-809 (Magee, Cain, & Thompson, 2011) and ask any questions. Additional information was then gathered from participants such as age and experience (service and video game). Subsequently, participants took part in the experiment. The specific testing procedure was determined by the participant group to which each of the participants was assigned. Upon boarding HMCS Corner Brook for the first time during this experiment, all participants received a safety briefing from a qualified submariner regarding the use of the EBS and the EEBD.

VCVS Familiarization and Skill Acquisition Session 1– Qualified and Experimental Groups Only

In order to accommodate work schedules and availabilities, Qualified participants used the VCVS aboard HMCS Corner Brook. However, to avoid incidental learning and to provide a quiet learning environment, all Experimental participants used the VCVS in Building N60, a classroom at CFB Esquimalt. The Control group did not participate in the VCVS familiarization and skill acquisition session as these participants were initially trained to isolate bulkhead 35 physically aboard HMCS Corner Brook (see Section 0).

At the beginning of the VCVS session, the laptop keyboard controls and functions associated with manoeuvring the participant's point of view within the VCVS were identified and demonstrated to all participants. Specifically, the experimenter demonstrated that the point of view could be controlled using the mouse, and that participants could manoeuvre within the VCVS using either the standard gaming "W/A/S/D" keys or using the cursor arrows (up, down, left, right). Additionally, participants were informed that the VCVS had a built-in map function that provided an aerial view of the deck that they were on and their spatial location on that deck within the VCVS. An information sheet explaining these controls and functions was provided to all participants and was available for reference whenever required during the VCVS session.

Once participants were sitting in front of the laptop, the experimenter loaded the VCVS software to begin the familiarization trial. In the familiarization trial, participants, using the mouse and keyboard controls, moved from the Jetty onto the Victoria Class submarine and down the main access hatch guided by the experimenter. Once aboard, participants were shown how to isolate bulkhead 35 within the simulated submarine environment, from both the forward and aft compartments. The experimenter verbally guided the participants to each valve location and identified the name, function and actions that were required in the simulation in order to shut the valves (i.e., click to turn the valve or locate and click on the correct ratchet to apply to the valve when required). During the familiarization trial, the compartment (i.e., forward or aft) that the participant began in from where the experimenter guided the participant through the isolation of bulkhead 35 was randomized to avoid order effects on learning. Participants had the opportunity to ask questions throughout the familiarization trial in the VCVS session.

After a quick break the experimenter loaded the VCVS software to begin the skill acquisition trials. At the beginning of each trial, one of six different starting locations (three starting locations in the forward and aft compartments) was randomly selected by the software. After activating the bulkhead 35 isolation task, the experimenter asked the participants to isolate bulkhead 35 from the compartment in which they were currently located. At the beginning of each trial in the VCVS, the participants were presented with an instructional prompt that listed the names of all six valves that were to be shut in order to successfully isolate bulkhead 35.

The participants then proceeded to interact with the VCVS in the following ways:

- Participants navigated through the VCVS using the mouse and keyboard controls, correctly locating, identifying, stating the function of, and shutting the six valves required to isolated bulkhead 35;

- Upon locating each valve, the participant placed the crosshairs (controlled by the computer mouse) on the valve. If this valve was one of the correct valves to shut, it would turn green. To simulate shutting the valve, the participant clicked (once with the left mouse button) on the valve at which time an instructional prompt was presented on the screen that identified the valve's name and function with a green checkmark indicating the valve had been successfully shut; and,

- In order to shut a valve that required a ratchet, a prompt first appeared which instructed the participant to locate the ratchet. In order to locate the ratchet, the participant located and "looked" at the correct ratchet in its storage bracket (using the mouse to position the crosshairs over it). Once the crosshairs were positioned over the correct ratchet, the ratchet turned green. The participant then clicked (once with the left mouse button) to pick up the ratchet which then disappeared from view. The participant was then presented with another instructional prompt to utilize the ratchet to shut the valve. To shut the valve, the participant first identified the correct valve to shut (by using the mouse to put the crosshairs over it). Once the crosshairs were placed over the correct valve, which turned green indicating the participant had identified the correct valve to shut, the participant clicked the valve (once with the left mouse button) to shut it. When the valve was clicked the ratchet reappeared in the VCVS, now applied on the valve, simulating the ratchet being used to shut the valve. The participant then received the instructional prompt that identified the valve's name and function along with a green checkmark which indicated the valve had been successfully shut. The last instructional prompt that appeared to the participant informed him to replace the ratchet. In order to replace the ratchet, the participant first positioned the crosshairs over the ratchet currently applied to the valve, which turned green indicating this was the ratchet that had to be replaced, and then the participant clicked the ratchet (once with the left mouse button). The ratchet disappeared off of the valve and reappeared immediately in the storage bracket, simulating the ratchet being stowed after use.

Upon successfully isolating bulkhead 35 in the VCVS, Qualified participants completed payment forms, which concluded their participation in the study. However, upon successfully isolating bulkhead 35 in the VCVS, Experimental participants were given directions to HMCS Corner Brook for their second participation session before being dismissed for the day.

Submarine Familiarization Session 1 – Control Group Only

The submarine familiarization session began with the experimenter demonstrating to Control participants how to isolate bulkhead 35 aboard HMCS Corner Brook from both the forward and aft compartments. During this demonstration, the experimenter guided the Control participants to each valve location, identifying the valve's name, function and the action required to shut the valve (i.e., turn the valve or apply a ratchet). The bulkhead compartment (forward or aft) from which Control participants were initially shown how to isolate bulkhead 35 was randomized by the experimenter to avoid order effects as in the VCVS training and familiarization session for the Experimental group. During the submarine familiarization session, Control participants had the opportunity to ask questions but were not given any additional opportunities to practise aboard. Upon completion of the submarine familiarization trial, participants were escorted off the boat; this concluded their participation in session 1.

Submarine Skill Acquisition Session 2 – Control and Experiment Groups Only

Two days following the familiarization session (either in the VCVS or aboard), Control and Experimental participants participated in the submarine skill acquisition session aboard HMCS Corner Brook. At this point participants were lead by the experimenter to one of six randomized starting locations (three in the forward and three in the aft compartment). Participants were then asked to isolate bulkhead 35 from the compartment in which they currently were located. Again, in order for a participant to complete the submarine skill acquisition session, they had to correctly locate, identify, explain the function and the action required to shut all six valves associated with isolating bulkhead 35 perfectly one time from either the forward or aft compartment. When they had successfully demonstrated the isolation of bulkhead 35, they completed a payment form and were escorted by the experimenter off HMCS Corner Brook, concluding their participation in the study.

4. Results

VCVS Utilization

The following sub-sections describe how Experimental participants utilized and interacted with the VCVS while learning how to isolate bulkhead 35.

Observed Learning Strategies

During the VCVS skill acquisition trials, Experimental participants were observed to engage in two distinct learning strategies while they trained on the VCVS. These two learning strategies emerged as the result of allowing participants to interact with and utilize the VCVS in whatever way they thought would benefit their ability to learn how to isolate bulkhead 35 on the Victoria Class submarine. The two strategies Experimental participants demonstrated when required to identify valve names and functions were:

- Reading the valve's name and corresponding function directly off the instructional prompt that was presented immediately after clicking on the valve; and,
- Generating an educated guess of the valve's name and function prior to clicking on the valve and then verifying their response with the correct answer provided.

VCVS Map View Activations

To determine how often the "Map View" function was utilized by both Qualified and Experimental participants, the VCVS log files were reviewed. Only the activations of the "Map View" function that were initiated by the participants during VCVS skill acquisition trials were included in the analysis (i.e., map view activations initiated by the experimenter to demonstrate the existence of the feature were not counted) to understand the frequency with which the "Map View" was utilized by Qualified and Experimental participants. Results indicate that on average, Qualified participants activated the "Map View" function 1.1 times during their participation, whereas the "Map View" function was never activated by the Experimental participants.

Strengths of the VCVS

The following sub-section describes the strengths associated with the VCVS.

Point of View Movement Controls

During the VCVS skill acquisition session, the keyboard control preferences associated with manoeuvring within the VCVS for each of the Qualified and Experimental participants were recorded and analyzed. The results showed that 40% and 60% of the Qualified and Experimental participants respectively, used the standard gaming letters "W/A/S/D". The remaining percentage of participants in each testing group used the cursor arrows (up, down, left, right) to manoeuvre within the VCVS. The two different methods of control demonstrate the VCVS's ability to accommodate different users' preferences (i.e., allowing users to use preferred keyboard controls).

Additionally, observations throughout the VCVS sessions led to conclusions that Qualified and Experimental participants were able to easily ascend and descend between the different deck levels using the ladders, as well as manoeuvre through bulkheads. The ease with which participants could move throughout the simulated environment could possibly be attributed to the automatic instructional flags presented within VCVS which identified required actions and their associated keyboard letter needed to correctly perform the action.

Qualitative Feedback

The qualitative feedback provided by the Experimental participants was analyzed and categorized to reflect general themes associated with using the VCVS to learn how to isolate bulkhead 35.

Comments Provided During and After VCVS Familiarization and Skill Acquisition Session

During the VCVS familiarization and skill acquisition session several Experimental participants indicated that they were frustrated by the inability to read any information off the valve VV803 environmental label located in the Senior Ratings Mess and inability to read parts of the information provided on valve VV608 environmental label within the VCVS. Since participants were told that they could use the environmental labels to identify the valve names and functions (as they would be able to do aboard the submarine), they were observed to be frustrated and disappointed.

Upon conclusion of the VCVS familiarization and skill acquisition session, several Experimental participants were asked to provide general comments about their experiences training and interacting with the VCVS. The majority of the Experimental participants commented that the graphics incorporated within the VCVS were quite good. Some of the participants remarked that the simulation had some of the best graphics that they had ever seen and/or interacted with when compared to other video games on the market. Some participants, however, commented on how they found it difficult to understand and recall the valve names and functions in English because French was their first language. Consequently, these participants explained that they felt their poor procedural performance was a result of this language barrier.

Comments Provided After Submarine Skill Acquisition Session

During the submarine skill acquisition session, one Experimental participant struggled to locate the ratchet required to close LPB 803. This participant identified that the reason he was struggling was because it was not located in the cabinet where he was trained to locate it within the VCVS. He commented that the ratchet in the simulation was located incorrectly (attached to the wall within the cabinet) compared to its real location aboard (attached to the inside of the cabinet door). This suggests that the participant had developed an understanding of the spatial location associated with the LPB 803 ratchet through his use of the VCVS.

After being physically aboard HMCS Corner Brook and having completed their participation in the VCVS study, several Experimental participants were asked or volunteered their thoughts about the VCVS and how realistic they felt the VCVS represented the actual submarine. Several participants commented that they believed the simulation was very realistic and representative of the true submarine environment. Some participants commented that they felt as though they had been quite prepared for the submarine skill acquisition session, specifically accrediting the VCVS with providing good spatial training of the various areas and levels within the submarine.

5. Technical Limitations And recommendations associated with the VCVS

This section identifies the technical limitations associated with the VCVS that were observed during the Experimental group's VCVS Familiarization and Skill Acquisition Session 1. Table 5-1 below summarizes the limitations that Experimental participants faced while interacting with and utilizing the VCVS.

Table 5-1: Technical Limitations and Proposed Recommendations Associated with the VCVS.

VCVS Technical Limitations and Proposed Recommendations		
#	**Technical Limitations**	**Recommendations**
1.0	During some of the testing sessions, the VCVS screen periodically froze. The frame delays decreased the overall fluidity of visual movements and had participants questioning the accuracy of their movement and actions/ inputs into the simulation.	Minimize VCVS frame delays to increase the fluidity and realism associated with the VCVS.
2.0	Participants could not read the valve name of VV608 and LPB 803 or the valve name and function of VV803 off of the environmental labels simulated within the VCVS. When this label could not be read in the VCVS as they could be aboard the real submarine, participants were observed to be frustrated. Experiencing the VCVS's inability to replicate an action that could be performed in real life, may reduce the realism and thus, overall credibility associated with the VCVS.	Allowing the user to move close enough to the environmental labels within the VCVS to read all valve labels, will increase not only the realism and credibility of the VCVS, but may also improve the overall effectiveness of the VCVS to procedurally train the bulkhead 35 isolation task.
3.0	Participants were observed to struggle more with shutting valves that required the use of a ratchet. As more and more participants were observed, it became clear that the controls required to shut a valve with a ratchet were non-intuitive.	*See section 5.1 below for a detailed recommendation regarding this issue.
4.0	Participants received a "Wrong Action" message when they clicked on the green coloured ratchet required to shut VV608. Participants were observed to be confused because they were clicking on an identified ratchet, presented in green, which they were trained to understand as an indicator of a correct ratchet selection. It was	When the user can turn a valve green (by using a computer mouse to position the crosshairs over the correct valve), the user (at the exact same viewing distance) should be able to shut the valve.

VCVS Technical Limitations and Proposed Recommendations		
#	**Technical Limitations**	**Recommendations**
	discovered that if the participant moved closer to the ratchet associated with VV608 and clicked again on the ratchet, the "Wrong Action" message disappeared and the typical instructional prompts associated with isolating VV608 were presented on the screen.	
5.0	A participant indicated that he was struggling to find the LPB 803 ratchet in the cabinet located in the Commanding Officer's cabin. Upon comparing the ratchet location in the VCVS to its location aboard HMCS Corner Brook, the reason this participant struggled to find the ratchet was because the ratchet in the simulation trained the participant to look in the cabinet when in fact aboard HMCS Corner Brook, the ratchet was attached to the cabinet door.	Ensure that the LBP 803 ratchet is positioned in the VCVS as it is located aboard HMCS Corner Brook.
6.0	When a participant was in front of the ascending ladder at bulkhead 35 and pressed the "R" letter as prompted to use ladder, the participant descended down the adjacent ladder to the Mast Well. Participants were observed to be very confused as they anticipated they would take the ascending ladder up to the control room.	If a user cannot use the ladder at bulkhead 35 to ascend to the control room, the instructional prompt (i.e., informing the user to press the letter "R" to use ladder) should be removed from the VCVS. The only way a user should be able to descend down to the Mast Well compartment is by positioning himself in front of the descending ladder (leading to the Mast Well) at bulkhead 35 and correctly following the instructional prompt.
7.0	In the VCVS, the door leading to the Sonar Cabinet Space was open, where aboard HMCS Corner Brook the door was found to be closed unless personnel were working within that area. As participants were not required to open the door in the VCVS this may have caused confusion for several participants who struggled with locating the VV803 valve in the Sonar Cabinet Space aboard HMCS Corner Brook.	Aboard HMCS Corner Brook, the Sonar Cabinet Space door was always shut unless personnel were working within this compartment. At the time of testing, it had not been determined if having the Sonar Cabinet Space door shut was a Victoria Class submarine standard or crew standard. Therefore, before the VCVS is redesigned (requiring user to open the door) further information upon this standard should be obtained to improve consistency between HMCS Corner Brook and the VCVS.
8.0	A few francophone participants were observed struggling and	Valve functions should be presented in both English and French.

VCVS Technical Limitations and Proposed Recommendations		
#	Technical Limitations	Recommendations
	becoming frustrated with recalling valve functions. More than one francophone participant commented that he had a difficult time understanding the functional meaning associated with the valves.	Incorporating both languages within the VCVS will provide a better learning environment for francophone users.

VCVS Recommendations for Technical Limitation 3.0

A Hierarchical Task Analysis (HTA)[2] was performed on shutting a bulkhead 35 isolation valve requiring a ratchet in real life aboard the submarine to understand how this task was executed within the VCVS. Table 5-2 presents the HTA results of the shutting bulkhead 35 valve requiring a ratchet.

Table 5-2: Tabular HTA for Shutting Bulkhead 35 Valve Requiring a Ratchet.

HTA for Shutting a Bulkhead 35 Isolation Valve Requiring Ratchet	
0. Shut off bulkhead 35 isolation valve with ratchet. Plan 0: Do 1 then 2 then 3 then 4 then 5.	
1.0 Retrieve correct ratchet. Plan 1: Do 1.1 then 1.2 then 1.3.	
Subtasks	1.1 Locate correct ratchet in storage bracket.
	1.2 Remove ratchet from storage bracket.
	1.3 Transport ratchet to valve area.
2.0 Apply ratchet to valve. Plan 2: Do 2.1 then 2.2.	
Subtasks	2.1 Locate correct valve.
	2.2 Slide ratchet head onto valve axel.
3.0 Shut valve. Plan 3: Do 3.1.	
Subtasks	3.1 Use ratchet to turn valve axel.
4.0 Remove ratchet off valve. Plan 4: Do 4.1.	
Subtasks	4.1 Slide ratchet head off valve axel.
5.0 Stow ratchet in storage bracket. Plan 5.0: Do 5.1 then 5.2 then 5.3.	
Subtasks	5.1 Transport ratchet to storage bracket area.
	5.2 Locate correct ratchet storage bracket.
	5.3 Place ratchet in storage bracket.

Upon reviewing the HTA and the results of the current experiment, it is suggested that Task 3.0 be maintained but that the sub-tasks associated with both Task 1.0 and Task 2.0 be combined into a single

[2] The HTA was first developed by John Annett and Keith Duncan, as cited in Shepherd and Stammers, 2005, p.140.

task. Also, the sub-tasks associated with Task 4.0 and Task 5.0 should be combined into a single task. Consequently, the following three tasks would be simulated within VCVS:

- VCVS Task 1Retrieve and apply ratchet to valve;
- VCVS Task 2 Shut valve; and,
- VCVS Task 3 Remove and stow ratchet.

Using these three tasks as a basis, the following recommendations can be made to increase the intuitive nature of this simulated task within the VCVS.

VCVS Task 1: Retrieve and apply ratchet to valve

The first recommendation is to have the instructional prompt instruct the user to locate and apply the ratchet, clearly explaining the task that should be executed. In working with the VCVS, the study team researchers had discussed the possibility of implementing a click and drag functionality to choose, transport and apply the ratchet in the VCVS. Upon greater analysis of the task, it is recommended that implementing a 'click and drag' functionality to execute this task within the VCVS would provide a more realistic representation of the actual physical task. It is suggested that this task be designed for execution as described in Table 5-3.

Table 5-3: Proposed User Actions to Execute VCVS Task 1.

VCVS Task 1: Retrieve and Apply Ratchet to Valve	Proposed User Actions
1.1 Locate correct ratchet in storage bracket.	Using computer mouse, user positions the crosshairs over the correct ratchet residing in the storage bracket. *Ratchet is visible to user and resides in storage bracket.
1.2 Remove ratchet from storage bracket.	With the crosshairs positioned over ratchet, user depresses left click button on computer mouse. *Ratchet remains visible to user in the storage bracket.
1.3 Transport ratchet to valve area.	User maintains left click button depression and drags ratchet from storage bracket to correct valve area. *Ratchet remains visible to user during dragging action.
1.4 Locate correct valve.	User positions ratchet on correct valve. *Ratchet remains visible to user residing on valve.
1.5 Slide ratchet head onto valve axel.	Once ratchet is on correct valve, user releases left click button, securing ratchet onto the valve. *Ratchet remains visible to user residing on valve.

VCVS Task 2: Shut Valve

Since Task 2.0 (Shut valve) is a distinct task, it is suggested that in order to shut the valve, the user should make a separate left click on the ratchet that they just applied to the valve (as described in Table 5-4). When the single left click is performed, the instructional prompt identifying the valve name and function should be presented and the ratchet should also provide a visual indication to the user that they have successfully shut the valve.

Table 5-4: Proposed User Actions to Execute VCVS Task 2.

VCVS Task 2: Shut Valve	Proposed User Actions
2.1 Use ratchet to turn valve axel.	Using computer mouse, user positions the crosshairs over the correct ratchet residing on the valve. With the crosshairs positioned over ratchet, user depresses and releases left click button on computer mouse. *Ratchet remains visible to user while making a 360 degree revolution.

VCVS Task 3: Remove and Stow Ratchet

In order to maintain functional consistency within this task, it is recommended that actions required of the user to remove and stow the ratchet be performed in a manner that is identical to proposed VCVS Task 1 above. It is suggested that VCVS Task 3 be designed within the simulation to be executed according to Table 5-5.

Table 5-5: Proposed User Actions to Execute VCVS Task 3.

VCVS Task 3: Remove and Stow Ratchet	Proposed User Actions
3.1 Slide ratchet head off valve axel.	Using computer mouse, user positions the crosshairs over the ratchet residing on the valve. With the crosshairs positioned over ratchet, user depresses left click button on computer mouse. *Ratchet remains visible to user residing on the valve.
3.2 Transport ratchet to storage bracket area.	User maintains left click button depression and drags ratchet from valve to storage bracket area. *Ratchet remains visible to user during dragging action.
3.3 Locate correct ratchet storage bracket.	User positions ratchet on correct storage bracket. *Ratchet remains visible to user, hovering over storage bracket.
3.4 Place ratchet in storage bracket.	Once ratchet is on correct storage bracket, user release left click button, securing ratchet in storage bracket.

VCVS Task 3: Remove and Stow Ratchet	Proposed User Actions
	*Ratchet remains visible to user, residing in storage bracket.

6. CAE PS Observations OF VCVS

In addition to the recommendations put forth in Section 5, DRDC Toronto requested that I (C. Kersten) provide additional thoughts and recommendations resulting from personal experiences interacting with and utilizing the VCVS as a training tool in preparation for this study. The following sub-sections identify recommendations that I believe may enhance the realism of the VCVS and to improve its overall effectiveness as a training tool.

Spatial Training

I believe that the VCVS is currently sophisticated enough to provide general spatial knowledge of the Victoria Class submarine. Evidence to support this belief arises from observing Experimental participants confidently perform correct spatial manoeuvres when isolating bulkhead 35 aboard HMCS Corner Brook. In addition, two Experimental participants were able to perform the bulkhead 35 isolation task perfectly during their first attempt aboard HMCS Corner Brook. In fact, one of these two Experimental participants was so eager to demonstrate the bulkhead 35 isolation task that he had to be asked to slow down (i.e., not walk/race so quickly ahead of me) so that I could observe and record his performance. Being able to perform the task perfectly, thereby executing both spatial and procedural knowledge correctly during the first time aboard HMCS Corner Brook is a persuasive indication as to the VCVS's ability to effectively train personnel on the spatial layout of the Victoria Class submarine.

Additionally, my own personal experiences training with the VCVS in preparation for conducting the study strengthens the belief that the VCVS can effectively train the spatial layout of the Victoria Class submarine. Upon boarding HMCS Corner Brook for the first time, with only previous exposure to the submarine's spatial layout through VCVS training, I was able to not only recognize and correctly identify compartments within the submarine, but also able to manoeuvre correctly to the general valve locations. Having such a great understanding of the spatial layout of HMCS Corner Brook when being only aboard for the first time, is a huge testament to the spatial training abilities of the VCVS.

However, the only recommendation that I could make to enhance the spatial training effectiveness of the VCVS would be to represent the valves more realistically within their complex and camouflaged environments. When aboard HMCS Corner Brook for the first time, I knew generally where to expect the valves to be located within the space, but had a little bit of difficulty locating valves VV801 and LPB 803. Specifically, I experienced that the immediate environments surrounding valves VV801 and LPB 803 (in both forward and aft compartments) were much more complex than simulated within the VCVS.

Procedural Training

Additionally, I believe that the following recommendations may improve the VCVS's ability to train the procedural knowledge associated with isolating bulkhead 35.

Generation of Valve Locations, Names and Functions

By clicking on a green coloured valve within the VCVS, the valve's name and function automatically appear. While this is an excellent way to first introduce each valve (green colour identifies valve and prompt explains name and function), the VCVS software should be designed to have subsequent levels of difficulty to challenge and appeal to the more experienced personnel. Requiring the user to locate, identify and explain valve functions on their own first before providing feedback, will increase the level of difficulty within the VCVS and provide a more complex training experience. Therefore, the current version could be considered the "Beginner" level to ensure that non-experienced users are introduced but not overwhelmed by the task. Whereas, a more "Senior" level version of the VCVS could be activated to challenge the more experienced users (i.e., provide a more difficult testing environment to improve memory).

Label Discrepancy

During the study, a discrepancy arose between valve VV607 and VV606 functional responses provided by Qualified participants to the functions presented in the VCVS. Review of the forward compartment environmental label, which lists each valve and function, identifies valves VV607 and VV606 functions to be associated with the Bathroom, matching the "Heads" responses provided by the Qualified participants. This discrepancy indicates that the VCVS valve functions need to be revised. NeLCoE should conduct a focus group with submariner trainers to determine acceptable valve functional meanings to be incorporated within the VCVS.

I additionally recognized that the valve environment labels did not match functions presented in the simulation. In the VCVS an association/ link between the valve environmental label to that of the accepted functional meaning should be presented to the user. For example, the valve environmental label identifies valve VV607 to be "A.T.U. 2 BHD Isolating Valve". Whereas, in the VCVS the functional meaning associated with VV607 is "Ventilation Supply Isolating Shut". From experience working with qualified submariners, I learned that the A.T.U. stands for "Air Treatment Unit" which means that it is a "Ventilation" valve. By explaining what the valve label acronym represents, the user can make the appropriate association between what is presented on the valve environmental label and its associated function.

Valve Direction

During the experimental team's familiarization/ qualification day aboard HMCS Corner Brook, qualified submariners identified the importance of understanding which direction a bulkhead 35 isolating valve has to be turned in order to be shut. More than one qualified submariner also indicated that one particular valve (VV803) required a different directional turn depending upon the compartment (forward or aft) in which it was being shut. Since directional training was not incorporated within the VCVS, the valve's shut direction was not tested during this study. However, these findings indicated that the direction of the turn is an important requirement in learning how to isolate bulkhead 35, which suggests that NeLCoE consider incorporating the directional turn associated with shutting each valve into the VCVS.

7. Strengths and Limitations of the Study

The following sub-sections identify the strengths and limitations associated with the VCVS study.

Strengths of the study

The experimenters were able to realistically represent the training protocol normally followed aboard the submarine by acquiring an understanding of the procedure through training with various qualified submariners aboard the submarine. In fact, the major strength associated with this study, was the ability to realistically replicate Victoria Class submarine bulkhead 35 isolation training aboard HMCS Corner Brook and within the VCVS simulated environment.

Limitations of the study

Scientific studies are not immune to limitations. Upon reflection, the following limitations were identified as potentially influencing the study's findings.

Unavoidable Submarine Incidental Spatial Learning

During the submarine skill acquisition sessions (involving Control and Experimental participants), opportunities arose for participants to receive spatial training that did not occur with the VCVS. The first opportunity where participants may have potentially gained additional spatial awareness of HMCS Corner Brook was when they participated in required safety briefings. The safety briefings were performed aboard HMCS Corner Brook at a convenient location which was determined by the qualified submariner who conducted the briefing. This provided the participant an opportunity to acquire spatial knowledge while transiting to the safety briefing location.

Additional and completely unavoidable opportunities for incidental spatial learning occurred between testing trials as the participants moved from the ending location of one trial to the starting location of the next trial. Since starting locations were randomized, the distance traveled and thus the amount of spatial exposure to the submarine varied between trials. Thus, there were two opportunities for incidental spatial learning, which varied inconsistently, during testing aboard the submarine that were not afforded to participants during testing with the VCVS.

Testing Criteria

In order to be qualified to isolate bulkhead 35, a trainee is required to demonstrate perfect performance one time from either a forward or aft approach to the bulkhead. In this study the participant had to locate, identify, describe the functions and actions associated with shutting all six valves without error or assistance from either a forward or aft compartment in order to achieve criterion. Consequently, no participants had to demonstrate perfect proficiency from both directions. Review of the starting locations that were randomly picked for the submarine skill acquisition testing sessions, revealed that some participants were only tested from one direction (i.e., demonstrate bulkhead 35 task only from a forward or aft approach). It could be suggested that these participants may have been at a slight advantage, repetitively tracing their spatial manoeuvres, never having to cross bulkhead 35 and reorient themselves with the mirrored valve locations.

Additionally, in comparing bulkhead 35 task from both compartments it was acknowledged that there were differences between the spatial location of the valve (i.e., aft of bulkhead 35 LPB 803 is hidden within a cabinet whereas forward of bulkhead 35 LPB 803 is exposed) and the method required for it to be shut (i.e., aft of bulkhead 35 LPB 803 requires a ratchet to shut, whereas forward of bulkhead 35 LPB 803 is a hand turn valve). Based upon these differences, it could be argued that it may be more difficult to perform this task from one compartment in comparison to the other. Again, because the starting location in which a participant had to isolate bulkhead 35 was randomized, some participants may have been required to isolate bulkhead 35 from the easier compartment.

Previous Submarine Exposure

As shown in Table 3-3 the Experimental and Control participants had little experience aboard submarines when compared to Qualified participants. One of the Experimental participants (20 minutes of exposure) and two of the Control participants (65 minutes and 16 hours of exposure) had some previous submarine exposure. It appears that their previous exposure to submarines had limited, if any, influence on their task performance. Comparing the submarine skill acquisition testing session results of these three participants to the participants within their group revealed that these three participants were not the most successful (i.e., did not achieve task performance criterion in fewest trials nor commit the fewest spatial/path errors). This finding suggests that a small amount of prior exposure to the submarine did not impact the overall results of the study.

Experimental Participants

As identified in Sections 5 and 6, the VCVS is not without its limitations. Observation of the Experimental participants while they practiced with the VCVS identified the following factors as potential influences on task performance.

Inability to Verify Procedural Learning

Since the VCVS and the study criterion did not restrict Experimental participants from reading valve names and functions directly off the screen during the VCVS familiarization and skill acquisition sessions, it is quite possible that Experimental participants had learned spatially but not procedurally (valve names and associated function) how to isolate bulkhead 35 prior to their submarine skill acquisition session. Since the aids were available during the VCVS sessions, it is not possible to know if a participant would have achieved task criterion without benefit of this aid (i.e., by relying on memory for the procedures). The evidence suggests that the Experimental participants may have not been as procedurally prepared for the submarine skill acquisition testing session as anticipated.

Legibility and Discrepancies with Valve Labels

The inability to read certain valve environmental labels within the VCVS and the discrepancies that arose between the real submarine environmental labels and functions presented within the VCVS, were two factors that could have affected the performance of the Experimental participants during the submarine skill acquisition session. It could be hypothesized that since Control participants were able to clearly read all valve environmental labels aboard the submarine, they were able to make direct functional associations between what the environmental label read and what they had to functionally verbalize in order to successfully complete the isolation task. Whereas, when Experimental participants could not read the valve environmental labels within the VCVS, they were unable to build strong functional associations, making it difficult to recall valve functions when reading valve environment labels aboard the submarine.

Language Barrier

The last factor that could have influenced the results of the study was the fact that the functions within the VCVS were presented only in English. As previously acknowledged, it was the francophone Experimental participants that were observed to particularly struggle with and even commented on their difficulties understanding the valve functions. Even though the Control and Qualified testing groups also had francophone participants, these participants were not observed to struggle as greatly as those in the Experimental group. Regardless of who was observed to struggle or not, a participant's ability to comprehend the functions (presented in English) in the VCVS was not controlled for and thus, may have influenced the results of the study.

8. Lessons Learned

The following sub-sections identify and describe the lessons learned during the conduct of the VCVS study.

Participant Safety Briefings

In addition to participants reading and signing consent forms, participants were required to participate in a safety briefing prior to their participation aboard HMCS Corner Brook. In these safety briefings participants learned how to apply and utilize both the EBS and the EEBD. As a safety measure, participants received this safety briefing so that if the unfortunate event of an emergency occurred aboard which required immediate evacuation, participants would be properly prepared to effectively handle the situation. Anytime human participants participate in studies where their participation puts them at risk (i.e., while aboard operational equipment), the experimenters must provide safety measures to mitigate risks associated with their participation. However, as previously mentioned, what was unanticipated was that these safety briefings provided participants with an opportunity to gain additional spatial awareness. To mitigate incidental learning opportunities, it is suggested that an area aboard the submarine close to the main access hatch, be designated as the area in which all safety briefings will take place.

Participant Reactions to Submarine Environment

Even though not a single participant in this experiment admitted to being claustrophobic while aboard HMCS Corner Brook, several participants commented upon the spatially constrained close quarters and compartments within which the submariners had to live and work. One participant, however, commented upon how much he disliked being aboard HMCS Corner Brook (showing signs of relief when escorted back onto the jetty), in addition to commenting upon the spatially constrained close compartments during his participation in both the VCVS familiarization and skill acquisition session and submarine acquisition session. Each time a participant expressed his dislike and/or commented on the spatial constraints associated with the submarine environment, the experimenters paid closer attention for signs and/or behaviours associated with claustrophobia. To try to gain a sense of how participants were adapting to this new environment, the experimenters asked participants while aboard the submarine how they were feeling and if a break was required. The lesson learned from this experience was that when subjecting participants to new and unfamiliar environments that have several spatially constrained areas, a participant's susceptibility to claustrophobia needs to be not only assessed and anticipated, but also the experimenter should have a realistic evacuation plan in the event that a participant were to experience such fears.

Operational Equipment

Another lesson learned from supporting the VCVS study is that no matter how much time is spent preparing for and planning how to execute a study, when conducting testing which requires real world operational equipment, the testing protocol and the testing schedule may be affected by unanticipated events and obstacles reducing the operational equipment's accessibility.

During the course of the VCVS study, the following unanticipated events were encountered that reduced access to HMCS Corner Brook:

- Cold moves to charge submarine batteries;
- Filming events; and,
- Slight delays due to rebalancing the submarine.

While these all resulted in slight testing delays and minimal impacts to the execution of the study, the important lesson learned was that scheduling ample testing time between participants was the best defence in diminishing the effects associated with delayed access to HMCS Corner Brook.

9. Comments provided By non-participants

In addition to the participants of this study, C. Kersten showed the VCVS to two experienced RCN submariners. Summarized in Table 9-1 below, are the general comments made about the VCVS during these two separate exposure sessions.

Table 9-1: Comments provided by non-participant during VCVS exposure sessions.

Non-participant Comments
Simulation graphics were very realistic.
Details (little specifics) upon equipment and various systems were amazing and well done.
The relative (proportional) dimensioning of equipment and systems seemed to be quite accurate and realistic to real life environment.
The “snake pit” area seemed to be empty and missing a lot of extra things (i.e. equipment, systems and valves) compared to real life “snake pit” area.
Indicated that the VCVS in the current state (i.e., having areas that are not completely developed and thus not entirely representative of the real boat areas such as snake pit), may mislead individuals upon how easy it is to locate particular valves because they are not camouflaged within their true complex environments (i.e., hidden by other valves, objects and/or equipment).
Believed that on-board training still remains the best method to train submariners.
Believed that in the absence of the gaining access to the real boat (submarine), the VCVS could be potentially used as a training platform and quite possibility be the next best thing to actual physical access to the boat (submarine).
Indicated that he could see the potential possibilities of expanding the VCVS to include additional tasks within different areas of the boat (submarine).
Expressed the RCN’s need for a boat (submarine) physical/ simulation based training platform in the near future.

10. Conclusion

Based upon my experiences and observations during the VCVS familiarization and skill acquisition sessions, and my personal experience training with the VCVS, I believe the VCVS is sufficiently sophisticated to provide general spatial training of the Victoria Class submarine. However, there are opportunities to improve the VCVS as indicated by the recommendations put forth in this contract report. Such improvements are expected to improve the effectiveness for training personnel on procedural tasks associated with the Victoria Class Submarine.

11. References

Magee, L., Cain, B., & Thompson, A. (2011). *Protocol Number: L-809 Training effectiveness of the Victoria Class Virtual Submarine (VCVS).* Toronto, Ontario. Defence Research and Development Canada.

Shepherd, A., & Stammers, R.B. (2005). Task Analysis. In J.R. Wilson & N. Corlett (Eds.), *Evaluation of Human Work* (pp.129 to 157). Boca Raton, USA; Taylor & Francis Group.

12. acronyms and abbreviations

The following list identifies the acronyms and abbreviations used throughout this technical report:

A.T.U.	Air Treatment Unit
CAE PS	CAE Professional Services (Canada) Inc
CFB	Canadian Forces Base
DMTE	*Director Maritime Training and Education*
DRDC	Defence Research and Development Canada
DWS	Duty Watch Supervisor (DWS)
EBS	Emergency Breathing System
EEBD	Emergency Escape Breathing Device
FWD	Forward
HMC	Her Majesty's Canadian
HMCS	Her Majesty's Canadian Ship
HREC	Human Research Ethics Committee
HSI	Human Systems Integration
HTA	Hierarchical Task Analysis
NeLCoE	*Canadian Navy eLearning Centre of Expertise*
PATs	*Personnel Awaiting Training*
RCN	*Royal Canadian Navy*
VCVS	Victoria Class Virtual Submarine

Tasks Executed by CAE Ps ThrougHout project

The following list identifies the tasks fulfilled by CAE PS during the conduct of this project:

a) *Attended project kick off meeting at DRDC Toronto;*

b) *Completed and obtained certification from "Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans Course on Research Ethics (TCPS 2: CORE);*

c) *Learned how to isolate Bulkhead 35 from both the forward and aft compartments;*

d) *Developed and revised marking criteria templates for* evaluating task performance in the VCVS and aboard HMCS Corner brook*;*

e) Conducted informal pilots at DRDC Toronto;

f) Prepared and gathered all documents required for study (marking sheet, consent forms, payment forms, instruction sheets and participant information sheets);

g) Trained by Subject Matter Experts (SMEs) upon isolating bulkhead 35 (from both the forward and aft compartments) on HMCS Corner Brook;

h) Created monthly progress reports;

i) Conducted experiment testing sessions aboard HMCS Corner Brook and in Classroom N60 on the Canadian Forces Base (CFB) Esquimalt, British Columbia (Qualified, Experimental and Control groups);

   i. Briefed participants upon study roles and rights associated with their participation;

   ii. Asked participants to complete consent and payment forms;

   iii. Trained participants how to isolation bulkhead 35 from the forward and aft compartments (in both the VCVS and aboard HMCS Corner Brook);

   iv. Manually testing and recording participant performance data during testing sessions;

j) Coded and entered manually recorded performance data into excel files;

k) Coordinated performance data backups (VCVS generated log files and performance data excel files);

l) *Returned experimental laptops to IT Support department* on CFB Esquimalt, British Columbia;

m) Attended a post study meeting at DRDC Toronto to;

   i. deliver participant performance data sheets (data manually recorded during study) and a CD which contained all performance data excel files from all 30 participants;

ii.converse over preliminary results obtained; and

iii.discuss summary report expectations (prepared and verified “Table of Contents”);

n) Performed descriptive statistics upon participant information;

o) Developed and delivered customized draft technical report;

p) *Revised draft technical report based upon client feedback received;*

q) *Submitted final technical report; and*

r) *Attended/ participated in meeting with client and the Canadian Navy eLearning Centre of Expertise (NeLCoE).*

Aft compartment VCVS Score Sheet

SIMULATION : AFT DECK VALVES

Session # ____

Trial # ____

Starting Location:__________________________________

Participant ID #: __________________________________

Tasks (No Order)	Participant Action/ Verbalization	Error	Help	Correct	Notes
	Path/ Location				
1) Shut off VV608					
1.1) Locate and pick up ratchet for VV608	Click on ratchet				
1.2) Use ratchet to shut off valve VV608	Locate VV608				
	Click on VV608				
	ID VV608				
	Function: FWD Battery Ventilation Shut				
1.3) Replace ratchet	Click on ratchet				
	Path/ Location				
2) Shut off VV607					
2.1) Shut off valve VV607	Click on VV607				
	ID VV607				
	Function: Ventilation Supply Isolation Shut				
3) Shut off VV606					
3.1) Shut off valve VV606	Click on VV606				
	ID VV606				
	Function: Bulkhead Exhaust Isolation Shut				
	Path/ Location				
4) Shut off VV803					
4.1) Shut off valve VV803	Click on VV803				
	ID VV803				
	Function: BH35 Sonar Cab Isolation Shut				

CAE

SIMULATION : AFT DECK VALVES

Session # ______________________________________ **Starting Location:**________________________________

Trial # ____ **Participant ID #:** _________________________________

Tasks (No Order)	Participant Action/ Verbalization	Error	Help	Correct	Notes
	Path/ Location				
5) Shut off LPB803					
5.1) Open LPB803 cupboard	Click on LPB803 cupboard door				
5.2) Enter cupboard	Press "E" key to enter cupboard				
5.3) Pick up ratchet	Click on ratchet for LPB803				
5.4) Use ratchet to shut off valve LPB803	Click on LPB803				
	ID LPB803				
	Function: LP Blower Suction from WSC Shut				
5.5) Replace ratchet	Click on ratchet				
5.6) Exit the LPB803 cupboard	Press "E" key to exit cupboard				
5.7) Close LPB803 cupboard	Click on LPB803 cupboard door				
	Path/ Location				
6) Shut off VV801					
6.1) Shut off valve VV801	Click on VV801				
	ID VV801				
	Function: WSC Supply Isolating Shut				

forward (FWD) compartment VCVS score sheet

SIMULATION : FWD DECK VALVES

Session # ____

Starting Location:__________________________________

Trial # ____

Participant ID #: ___________________________________

Tasks (No Order)	Participant Action/ Verbalization	Error	Help	Correct	Notes
	Path/ Location				
1) Shut off VV608					
1.1) Locate and pick up ratchet VV608	Click on ratchet				
1.2) Use ratchet to shut off valve VV608	Locate VV608				
	Click on VV608				
	ID VV608				
	Function: FWD Battery Ventilation Shut				
1.3) Replace ratchet	Click on ratchet				
	Path/ Location				
2) Shut off VV607					
2.1) Shut off valve VV607	Click on VV607				
	ID VV607				
	Function: Ventilation Supply Isolation Shut				
3) Shut off VV606					
3.1) Shut off valve VV606	Click on VV606				
	ID VV606				
	Function: Bulkhead Exhaust Isolation Shut				
	Path/ Location				
4) Shut off VV803					
4.1) Shut off valve VV803	Click on VV803				
	ID VV803				

CAE

SIMULATION : FWD DECK VALVES

Session # ______________________________________ Starting Location:________________________________

Trial # ____ Participant ID #: _________________________________

Tasks (No Order)	Participant Action/ Verbalization	Error	Help	Correct	Notes
	Function: BH35 Sonar Cab Isolation Shut				
	Path/ Location				
5) Shut off LPB803					
5.1) Shut off valve LPB803	Click on LPB803				
	ID LPB803				
	Function: LP Blower Suction from WSC Shut				
	Path/ Location				
6) Shut off VV801					
6.1) Locate and pick up ratchet VV801	Click on ratchet				
6.2) Use ratchet to shut off valve VV801	Click on VV801				
	ID VV801				
	Function: WSC Supply Isolating Shut				
6.3) Replace ratchet	Click on ratchet				

Aft compartment Submarine score sheet

SUBMARINE : AFT DECK VALVES

Session # ______________________________________ **Starting Location:**________________________________

Trial # ____ **Participant ID #:** _________________________________

Tasks (No Order)	Participant Action/ Verbalization	Error	Help	Correct	Notes
	Path/ Location				
1) Shut off VV608					
1.1) Locate and pick up ratchet	ID ratchet				
1.2) Locate VV608	ID VV608				
1.3) Use ratchet to shut off valve VV608	Connect ratchet on valve VV608				
	Use ratchet to turn valve VV608				
	Function: FWD Battery Ventilation Shut				
1.4) Replace ratchet	Disconnect ratchet from valve VV608				
	Return ratchet to proper location				
	Path/ Location				
2) Shut off VV607					
2.1) Shut off valve VV607	ID VV607				
	Turn valve VV607				
	Function: Ventilation Supply Isolation Shut				
3) Shut off VV606					
3.1) Shut off valve VV606	ID VV606				
	Turn valve VV606				
	Function: Bulkhead Exhaust Isolation Shut				
	Path/ Location				
4) Shut off VV803					
4.1) Shut off valve VV803	ID VV803				
	Turn valve VV803				

CAE

SUBMARINE : AFT DECK VALVES

Session # ____ **Starting Location:**__________________________________

Trial # ____ **Participant ID #:** ___________________________________

Tasks (No Order)	Participant Action/ Verbalization	Error	Help	Correct	Notes
	Function: BH35 Sonar Cab Isolation Shut				
	Path/ Location				
5) Shut off LPB803					
5.1) Open LPB803 cupboard	Open LPB803 cupboard door				
5.2) Enter cupboard	Enter LPB803 cupboard				
5.3) Locate and pick up ratchet	ID ratchet				
5.4) Use ratchet to shut off valve LPB803	ID LPB803				
	Connect ratchet on LPB803				
	Use ratchet to turn LPB803				
	Function: LP Blower Suction from WSC Shut				
5.5) Replace ratchet	Disconnect ratchet from LPB803				
	Return ratchet to proper location				
5.7) Exit the LPB803 cupboard	Exit cupboard				
5.8) Close LPB803 cupboard	Close LPB803 cupboard door				
	Path/ Location				
6) Shut off VV801					
6.1) Shut off valve VV801	ID VV801				
	Turn valve VV801				
	Function: WSC Supply Isolating Shut				

Forward (FWD) compartment submarine score sheet

SUBMARINE : FWD DECK VALVES

Session # ___________________________________ **Starting Location:**___________________________

Trial # ______________________________________ **Participant ID #:** ___________________________

Tasks (No Order)	Participant Action/ Verbalization	Error	Help	Correct	
	Path/ Location				
1) Shut off VV608					
1.1) Locate and pick up ratchet	ID ratchet				
1.2) Locate VV608	ID VV608				
1.3) Use ratchet to shut off valve VV608	Connect ratchet on valve VV608				
	Use ratchet to turn valve VV608				
	Function: FWD Battery Ventilation Shut				
1.4) Replace ratchet	Disconnect ratchet from valve VV608				
	Return ratchet to proper location				
	Path/ Location				
2) Shut off VV607					
2.1) Shut off valve VV607	ID VV607				
	Turn valve VV607				
	Function: Ventilation Supply Isolation Shut				
3) Shut off VV606					
3.1) Shut off valve VV606	ID VV606				
	Turn valve VV606				
	Function: Bulkhead Exhaust Isolation Shut				
	Path/ Location				
4) Shut off VV803					
4.1) Shut off valve VV803	ID VV803				
	Turn valve VV803				
	Function: BH35 Sonar Cab Isolation Shut				
	Path/ Location				
5) Shut off LPB803					
5.1) Shut off valve LPB803	ID LPB803				
	Turn valve LPB803				
	Function: LP Blower Suction from WSC Shut				
	Path/ Location				
6) Shut off VV801					
6.1) Locate and pick up ratchet	ID ratchet				
6.2) Use ratchet to shut off valve VV801	ID VV801				
	Connect ratchet on VV801				
	Use ratchet to turn VV801				
	Function: WSC Supply Isolating Shut				
6.3) Replace ratchet	Disconnect ratchet from VV801				

SUBMARINE : FWD DECK VALVES

Session # ____ **Starting Location:**______________________________

Trial # ____ **Participant ID #:** ______________________________

Tasks (No Order)	Participant Action/ Verbalization	Error	Help	Correct	
	Return ratchet to proper location				

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13. ABSTRACT

CAE Professional Services (Canada) Inc. (CAE PS) was contracted by Defence Research and Development Canada (DRDC) Toronto to conduct work in accordance with a Call-up under Contract Number W7711-068111. The intent of the Call-up was to provide experimental support to DRDC Toronto in the evaluation of the Victoria Class Virtual Submarine (VCVS); DRDC Toronto designed the experiment and CAE PS assisted in the execution of the project. The evaluation of the VCVS was conducted in accordance with Protocol Number L-809 (Magee, Cain, & Thompson, 2011), an experimental protocol approved by the DRDC Human Research Ethics Committee (HREC).The VCVS is a game-based software program designed to deliver training to military personnel in a simulated submarine environment. This document describes the implementation of the protocol, provides qualitative findings and identifies the limitations and lessons learned from the conduct of the work. The results of the behavioural studies are reported separately by DRDC Toronto.

Recherche et développement pour la défense Canada (RDDC) Toronto a attribué un contrat à CAE Services professionnels (Canada) Inc. (CAE SP) en vue d'effectuer le travail conformément à la commande du numéro de contrat W7711-068111. L'objectif de cette commande était de fournir un soutien expérimental à RDDC Toronto dans le cadre de l'évaluation du sous-marin virtuel de la classe VICTORIA (SVCV); RDDC Toronto a conçu l'expérience et CAE SP a participé à la réalisation du projet. L'évaluation du SVCV a été menée conformément au numéro de protocole L-809 (Magee, Cain et Thompson, 2011) : un protocole expérimental approuvé par le Comité d'éthique en matière d'étude sur des sujets humains (CEESH) de RDDC. Le SVCV est un logiciel basé sur le jeu conçu afin de donner de la formation aux militaires dans un environnement de sous-marin virtuel. Le présent document décrit la mise en œuvre du protocole, présente les résultats qualitatifs et détermine les limites et les leçons retenues de la réalisation du travail. Les résultats des études sur le comportement font l'objet d'un rapport distinct de RDDC Toronto.

14. KEYWORDS, DESCRIPTORS or IDENTIFIERS

virtual environment; Victoria Class submarine; emergency procedures; virtual environment; training effectiveness